BREEDING, MOVEMENTS, AND CONSERVATION OF IBISES (THRESKIORNITHIDAE) IN AUSTRALIA

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Summary

Flooding at any season stimulates the breeding of ibises, and the white ibis, *Threskiornis molucca* (Cuvier), responds earlier than the straw-necked ibis, *T. spinicollis* (Jameson). Band recoveries show that both species disperse widely throughout Australia from breeding centres in the south.

Measures are proposed for management of the Macquarie Marshes, New South Wales, as a waterfowl reserve in which the limited volume of controlled water would be utilized economically to ensure that breeding of ibises coincides with the spring emergence of the Australian plague locust, *Chortoicetes terminifera* Walker.

I. INTRODUCTION

Three species of ibis breed in Australia. The most abundant of these, the straw-necked ibis, *Threskiornis spinicollis* (Jameson), occurs throughout the mainland and has visited Tasmania (Green 1959*b*) and New Guinea (Slater 1958), but it is not recorded elsewhere; there is no closely allied form. The white ibis, *T. molucca* (Cuvier), is also common and has a similar distribution throughout the continent, but is rare in the south-west; it has occurred in Tasmania (Green 1959*a*) and New Zealand (Stidolph 1927). The breeding range of the white ibis includes New Guinea and the Moluccas, where it merges with the very similar sacred ibis, *T. aethiopica* (Latham), of Asia, Africa, and Europe. The glossy ibis, *Plegadis falcinellus* (L.), is less abundant in Australia, especially in the south; it is uncommon in Victoria and a rare vagrant to Tasmania and New Zealand (Stidolph 1944), but it extends across Eurasia and Africa to south-eastern North America. Within their geographical ranges the three species tend to avoid arid areas (there are few records for the centre and central south of Australia), to remain at low altitudes, and to concentrate wherever recent rains have produced the flooding that sustains breeding. Thus the vagaries of Australian rainfall cause major shifts in the distribution of ibises, as in other waterbirds (Frith 1959).

The straw-necked ibis is the peculiarly Australian species, and on this account alone it merits some measure of conservation. Although it often feeds on terrestrial invertebrates and frequents dry as well as wet habitats, the essential dependence of this species and the white ibis on aquatic foods and on suitable water conditions for breeding has been shown (Carrick 1959). As natural waters in Australia come increasingly under control for agricultural and other purposes, with consequent diminution of flooding, the breeding of these waterbirds must be seriously affected. Now is the time to consider their requirements and to seek practicable measures of habitat and water manipulation which will ensure their survival.

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A more intensive study than has been possible in the present instance would be required to establish the precise conditions of water, food supply, nest-sites, and other factors which initiate and sustain successful breeding, and which determine the distribution and regional movements of ibises throughout Australia. Comparative data on breeding have been obtained from several waters of diverse character used by them, but these represent only a fraction of the known breeding-places. Continuous study at each locality was not possible, and visits, often as opportunist as ibis breeding, were supplemented by information from local observers; this was good in the case of Kow Swamp, thanks to the interest of Mr. C. R. G. Reid of Gunbower, but poor in the case of less accessible swamps such as the Macquarie Marshes, where aerial reconnaissance was necessary. The food samples and feeding habits have been discussed (Carrick 1959), and seasonal gonad development of the same specimens can now be related to environmental conditions. Banding of young straw-necked ibises and white ibises at several breeding centres has produced results which give some idea of their dispersal movements throughout Australia, and field observations in New South Wales add to this.

In this paper the ecological requirements of ibises are considered, especially in relation to breeding, with particular reference to a main breeding centre in New South Wales, the Macquarie Marshes, the flooding of which will be affected by the Burrendong Dam, near Wellington, which is to be completed about the end of 1964. It is recommended that conservation measures based on the essential needs of ibises and other waterfowl, and making minimal demands on the water supply, should be put into effect.

II. Breeding

The information available on breeding at five centres during 1952–1957 is summarized in Figure 1. The extensive Macquarie Marshes and Booligal Swamp are comparable in that each is flooded after heavy rain in the headwaters of the Macquarie River and Lachlan River respectively, which flow westward from the Great Dividing Range and are not dammed at present. These rains are unpredictable in season and quantity, so the marshes are subject to prolonged or to "flash" floods at any time of year and are often dry for long periods. Kiewa Swamp near Albury is a permanent marsh (Plate 1, Fig. 1), which receives a moderate flood each spring from the melting snow of the Victorian Alps, supplemented by variable rains, often in winter. A mile distant, Ryan's Creek is an anabranch of the Murray River, and its water level is controlled by the output of the large Hume Weir reservoir a few miles upstream; the spring release of water for irrigation may be extended by overflow due to winter rains. Two hundred miles downstream, Torrumbarry weir controls the flow of water through Kow Swamp, a natural marsh embanked to form an irrigation reservoir on a diversion of the Murray River.

In the breeding of ibises vegetation fulfils the purely physical need of supporting the nests above water level, where the site can be surrounded by water and where numbers of nests can be concentrated for protection from ground and

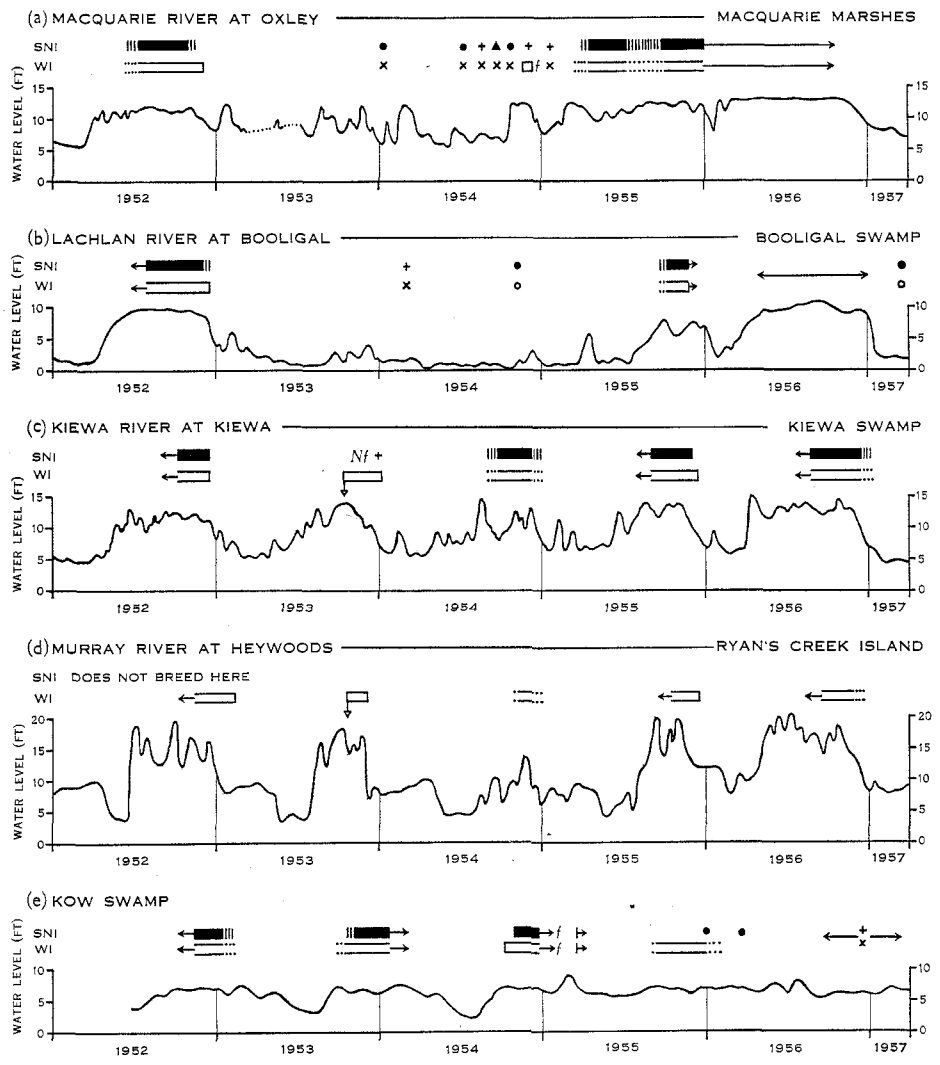

Fig. 1.—Breeding of ibises in relation to water levels. The four river levels (*a*) to (*d*), taken at the nearest recording station upstream from the breeding locality, show similar but much greater fluctuations than the water at the nesting colonies. In the case of (*e*), the water level is that of the breeding-place. Egg-laying periods are shown by broad bands, solid for straw-necked ibis (SNI) and open for white ibis (WI). Where duration of laying is known only approximately, e.g. from subsequent observation of young, bands are extended by lines or dots. Horizontal arrows indicate when breeding is known to have occurred, but detailed information is not available. Small vertical arrows show where date of first clutch laid was recorded. Nest-building not followed by laying is shown by *N*, and failure of the colony by *f*. Some occasions when the numbers of ibises present are significant are shown by symbols for straw-necked ibis and white ibis respectively: ● and ○, absent or very scarce; + and ×, few hundred; ▲, thousand or more.

avian predators. It also supplies nest material, usually that of the site. Clumps of lignum, *Muehlenbeckia cunninghamii* (Plate 2, Fig. 1), and beds of reeds, *Eleocharis* spp. (Plate 1, Fig. 3), or cumbungi, *Typha* spp., are favoured by both species, but in the presence of floodwaters the straw-necked ibis will nest on dry ground where there are no trees, bushes, or reeds (Plate 2, Fig. 2). Ground-nesting by the straw-necked ibis has been recorded by Carter (1904). Both species often nest together and are presumably reproductively isolated by behavioural mechanisms, among which the yellow skin under the wing of the straw-necked ibis and corresponding red skin of the white ibis are probably of specific significance, as the birds display with wings flapping. Only the white ibis has been found to nest in trees (Plate 2, Fig. 3), so it is the only species at Ryan's Island, which is entirely tree covered.* Both species roost in trees, preferably in swamps.

The relationship between breeding of both the straw-necked ibis and the white ibis and a rise in water level is evident at each of these locations (Fig. 1). It is most clearly seen at inland swamps such as Booligal, which undergo enormous water fluctuations and are virtually deserted by ibises during drought. The similar situation at Lake Bullawarra on the Bulloo River in south-west Queensland illustrates how changeable is the ibis population of such waters; normally very shallow and with few or no ibises, this lake flooded in March 1955 and by April 23 there was a large colony of white ibises with young and eggs and some straw-necked ibises with eggs; these birds dispersed, and at the next flood in January 1956 a straw-necked ibis colony began to lay on February 25 and built up to thousands, of which only a few were white ibis, throughout the autumn and winter floods (M. Schrader, personal communication). Many such examples from dry inland areas demonstrate the ability of ibises to locate and respond to suitable flood conditions.

Observations at nesting colonies have shown that display, building, and laying follow a significant flooding of the swamp and that nests are usually built over a water depth of 2–3 ft, but sometimes less, and in the case of the straw-necked ibis even on dry ground surrounded by floodwater. When both species are present before the flood starts there is evidence that the white ibis responds more quickly than the straw-necked ibis; the former species is ready to lay in 3–4 weeks, and the latter a similar period later. At Kiewa in 1953, the water level began to rise in mid September and many white ibises laid from October 15 onwards; early in November, when the straw-necked ibises had flattened an area of reeds and begun to build, and when their testes were mature but ovaries only half developed, the flood receded and further nesting of straw-necked ibises ceased, though white ibises continued to lay during November and December and succeeded in rearing young. In the Macquarie Marshes, a rapid flood rise in mid October 1954 was followed by establishment of several small colonies of white ibis during November (Fig. 1(*a*)), but the brief flood drained back in December, and by January there was no sign of nesting or of fledged young. At Kow Swamp on

* *Note added in proof.*—The straw-necked ibis has been reported nesting in trees at Phillip Island, Victoria (J. McKean, personal communication) and at Bool Lagoon, South Australia (J. Hood, personal communication).

November 6, 1954, many white ibises had eggs and chicks, but straw-necked ibises had eggs only. White ibises frequently nest in small groups of a few pairs, and isolated pairs or groups occur in the larger and more concentrated colonies of straw-necked ibis, and even among nesting cormorants (Phalacrocoracidae), spoonbills, *Platalea* spp., and herons (Ardeidae).

It has been suggested (Frith and Davies 1961) that the straw-necked ibis bred earlier than the white ibis in the Adelaide River, Northern Territory, in 1957, in contrast with the usual situation in inland New South Wales. However, earlier cessation of breeding does not necessarily mean earlier onset; it can be obscured by the addition to the colony of one species over a longer period than the other, owing to more birds being available, or to water conditions remaining suitable for the breeding of white ibis only. It is not certain that both species were present before March when flood conditions first favoured the breeding of ibises, nor whether juvenile white ibises, as well as straw-necked ibises, were on the wing by May. It is unlikely that a specific character of this kind would differ regionally in such nomadic species, which are each likely to be genetically homogeneous. Also, it seems significant, and in keeping with results from south-eastern Australia, that in 1958, a dry year in the Northern Territory, the white ibis succeeded in breeding there but the straw-necked ibis apparently failed.

The situation at the Macquarie Marshes in 1954 and 1955 clearly illustrates that suitable flood conditions, and not day length, temperature, local rainfall, or even abundant food supply, are the essential proximate stimulus for breeding. In July 1954 the swamp contained small numbers of white ibises only; these increased during August–September, when there was also a large influx of straw-necked ibises. Testes were about one-third developed and ovaries had emerged from the non-breeding regression; it was obvious that both species were ready to respond to appropriate breeding stimuli. Apart from a slow flow in the main water channels, where white ibises fed, the marsh was dry. In the first week of September, extensive hatchings of the Australian plague locust, *Chortoicetes terminifera* (Walk.), began throughout the region, and by early October large swarms of nymphs provided superabundant food for the straw-necked and some white ibises, which, however, showed no increase of gonad size nor sign of nesting. During October several good falls of rain occurred in the area, but the straw-necked ibises steadily vacated the Macquarie Marshes and were later reported in large numbers nesting at Lake Cowal, 200 miles to the south, and at Lake Narran, 80 miles to the north. This exodus occurred just before the October–November flood which enabled the remaining white ibises to breed in the Macquarie Marshes.

The readiness of ibises to breed at any time of year is shown by the egg-laying records obtained during 1952–1957 in New South Wales, southern Queensland, and along the Murray River. While it is no doubt true that most nesting commences during September to December, these figures are influenced by localities such as Kiewa Swamp and the Murray River waters, which enjoy a fairly dependable spring flood and where some nesting, especially of white ibises, occurs every year. More data from the many inland swamps where vast colonies, in which the straw-

necked ibis usually predominates, breed intermittently would tend to balance the monthly distribution of nesting and of the numbers of birds involved:

	J	F	M	A	M	J	J	A	S	O	N	D
Straw-necked Ibis	2	0	1	1	1	1	2	2	5	8	10	9
White Ibis	4	1	1	1	1	1	2	2	8	15	18	16

These figures include the layings which continue for weeks and sometimes months after nesting starts, and which represent the addition of new individuals to the colony and doubtless also the repeat layings of birds whose nests have failed. Failures have resulted from flooding of nests, which can occur naturally. It is also due to unfortunate water control, as at Kow Swamp in February 1955 (Fig. 1(*e*)), and to natural draining-back of floodwaters which leads to desertion of nests when the area is no longer under water, as after the flash flood in the Macquarie Marshes in late 1954 (Fig. 1(*a*)). It also occurs when water is cut off from Murray River effluents during forestry operations (K. L. S. Harley, private communication). There is no direct proof that successful breeders proceed with further layings as each brood is fledged, but years of widespread and continuous flooding, such as 1955 and 1956 throughout inland New South Wales, resulted in prolonged breeding activity (Fig. 1(*a*)(*b*)) well after the supply of birds seeking suitable conditions must have been exhausted. Adult ibises are wary birds and difficult to trap and mark; attempts to do so at the nest led to desertions, and even if successful it would still be a formidable task to obtain records of a nomadic species which nests colonially in swamps.

The nesting cycles of the straw-necked ibis and the white ibis are similar. The usual clutch is three or four eggs, the incubation period is 3½ weeks, fledging occurs 4 weeks after hatching, and both parents brood and feed the young. The latter, in and out of the nest, solicit food by insistent calling accompanied by flapping of the wing nearer to the adult (Plate 1, Fig. 2). They wrap this wing round the parent's neck to pull its head down in order to reach the food items which are regurgitated intact from the capacious crop into the adult's throat (Plate 2, Fig. 3). The food has been described (Carrick 1959) and the young are fed for about 2 weeks after they leave the nest. Observations from a hide in the colony at Kiewa of adults returning with food, refusing to feed importunate young indiscriminately, but calling until they had established vocal contact with young at first unseen, leave no doubt of the continuance of the parent–nestling bond and of the vocal basis of recognition. The juveniles are easy to distinguish by their short straight bills, and it is fully 3 months before the long sickle-shaped bill is developed. Adults undergo a postnuptial moult but it is not known whether, under favourable breeding conditions, there may be a succession of broods between moults, nor how soon after moulting the gonads are again able to respond to flood conditions.

III. Movements

Evidence on the movements of ibises is available from observations of their presence or absence, and their abundance, at breeding-places and elsewhere, as well as from the results of banding. Up to June 1961, 5339 young straw-necked

ibises and 1397 young white ibises had been banded at 15 breeding-places in south-eastern and south-western Australia; 41 and 22 birds respectively had been recovered up to January, 1962. The observational and banding coverage, especially throughout the northern half of Australia, is not adequate to reveal the complex movements that ibises undoubtedly make, and questions of sedentary habit and of constancy of return of individuals to breeding-places are likely to remain unanswered until adults can be banded and studied more intensively.

The significant recoveries of banded birds (Fig. 2) show that many young of both species scatter widely from their natal colonies and maintain this wide dispersion during subsequent years. The arrows on the map give no indication of the circuitous journeys which older birds in particular may have performed. There is evidence of considerable movements by young ibises as soon as they have fledged; in Western Australia a straw-necked ibis travelled 630 miles within 6 weeks, and white ibises from Kow Swamp in Victoria went 70 miles in 2 weeks and 790 miles within 3 months of being banded. The fastest long-distance performance was made by a straw-necked ibis that went from Gin Gin near Perth to Arnhem Land within 7 months, at the rate of at least 60 miles a week (probably much more if the indirect route and date of arrival at the recovery point were known). The longest journey, almost 2000 miles by direct measurement, was made by a white ibis from Kerang, Victoria, to New Guinea. Vidgen (1921) describes large flocks of white ibises to the north-west of Thursday Island migrating to and from New Guinea. There appears to be only one recorded observation (Slater 1958) of the straw-necked ibis in New Guinea, a surprising fact in view of the abundance of this mobile species in the Cape York Peninsula (Thomson 1935) and throughout the north of Australia generally. A few white ibises and glossy ibises only were seen in October 1960 by members of the Royal Australasian Ornithologists' Union in the Port Moresby district (W. R. Wheeler, personal communication). Thus the 6-year old bird from the Macquarie Marshes, recovered at Mulgrave Island, halfway across the Torres Strait, was near the northerly limit of range of the straw-necked ibis.

The distribution of recoveries practically all round the compass from the banding-places is well shown by the results of banding 2600 young straw-necked ibises in the Macquarie Marshes, New South Wales, in May 1955, and 324 of the same species at Gin Gin, Western Australia, during 1956–1961. The records in general show a marked coastal and northward movement by both species, though some of the Macquarie Marsh straw-necked ibises were in the Murray Valley from 3 to $6\frac{1}{2}$ years after being banded. It is clear that there is much intermingling of birds born throughout the breeding range of these species, and it would seem to be only a matter of time before banding demonstrates transcontinental and even wider movements. Individuals born in the same colony in the same season may be far apart at later dates, and some are still close to their birthplace, e.g. the 11-month old straw-necked ibis near Goose Lagoon, Port Fairy, Vic. There is evidence for some constancy of individuals in the nomadic flocks; two straw-necked ibises from the Macquarie Marshes were reported 25 and 26 months later from the same mission station on the Cape York Peninsula, and a white ibis of similar

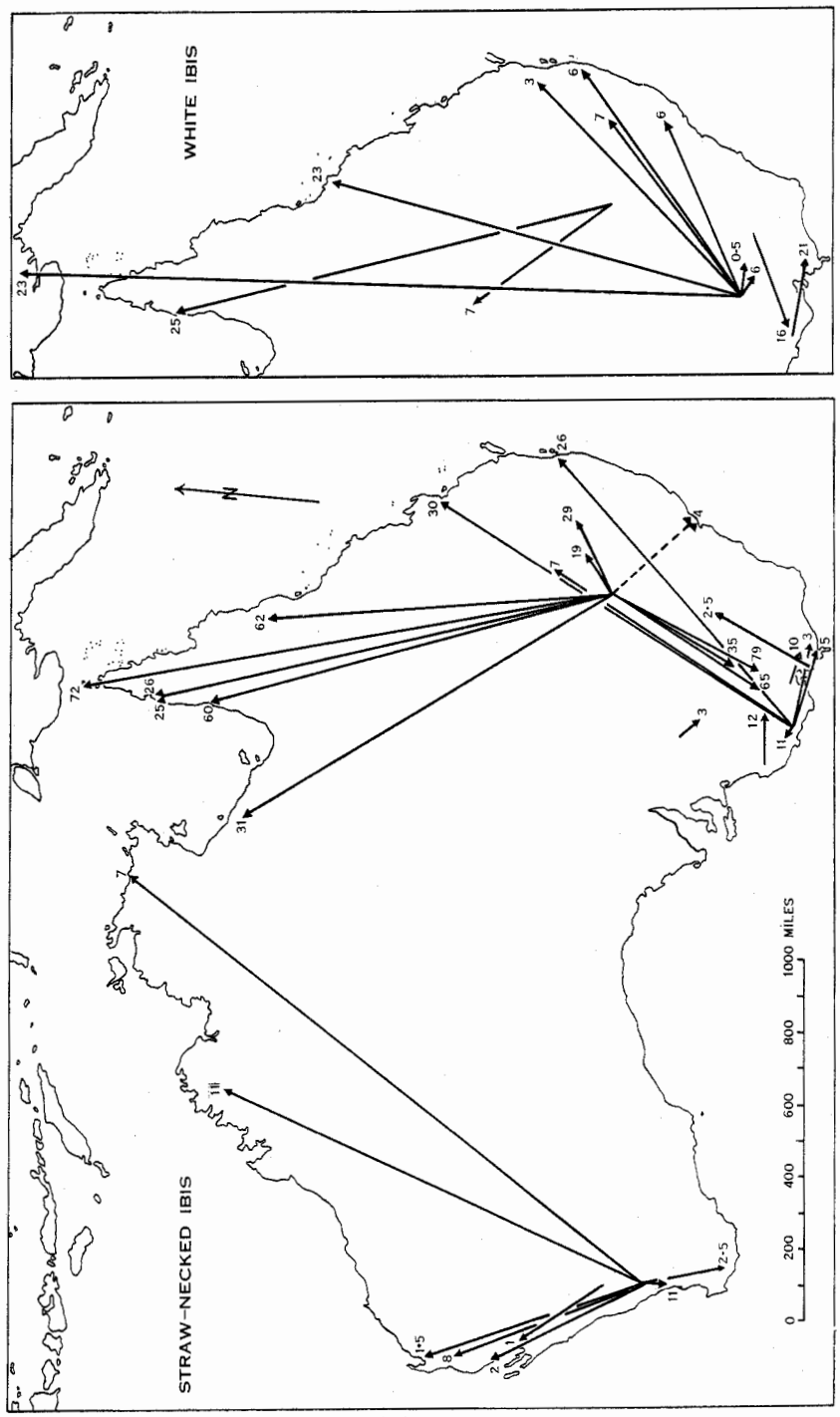

Fig. 2.—Dispersal of ibises banded as young at breeding colonies in Australia during 1955–1961 and recovered up to January 1962. Each arrow connects the places of banding and recovery of one ibis, but gives no indication of the actual route taken by the bird. The number at each arrow-head is the time in months since the bird was banded. The broken arrow is a sight record of two banded ibises. Records of birds up to 3 months old recovered within 50 miles of the banding-place are omitted.

origin was found only 50 miles distant at the same time; also, two banded straw-necked ibises were seen together in a flock near Sydney 4 months after the first banding of ibises in Australia in May 1955 at the Macquarie Marshes.

Many factors bias the chance of recovery of bands in species such as these, and some are difficult to assess; deductions about the true dispersion of the marked sample, especially the apparent gaps in its distribution, have to be made with caution. Absence of records from Tasmania, where ibises are rare visitors and do not breed, and from arid central–southern Australia, is understandable, but the fact that none have come from the lower Murray and coastal South Australia suggests lack of westerly dispersal from the colonies in Victoria and New South Wales. The rarity of subsequent recoveries of bands from the breeding swamps and the many inland waters of eastern Australia doubtless reflects the sparsity of the human population and the improbability of their contact with this type of waterbird. Birds reported from the thinly populated north coasts of Australia and from New Guinea were mostly speared or shot for food by aborigines, whose culinary interest in them could well be a more important factor in band recoveries than the greater density and education of the more civilized populace.

Some evidence of the nomadic movements of adult ibises in search of water conditions suitable for breeding has been discussed. The virtual absence of these and similar waterbirds from a large area of central western New South Wales during drought was confirmed by a field survey in January, 1954, when the Lachlan River ran low for two years (Fig. 1(*b*)). During July–August 1954 some information on ibis movements was obtained on a tour via the Macquarie Marshes to Cunnamulla in south-western Queensland, then across to Brisbane and the north-east coast of New South Wales, and finally via Moree to the Macquarie Marshes again. Early in July the Marshes contained only a few white ibises and, apart from occasional birds of either species, the only flock seen that month was about 250 straw-necked ibises on the wing a hundred miles west of Cunnamulla where all waters were low. Coastal paddocks and estuarine mudflats around Brisbane and the Clarence River Estuary contained considerable numbers of straw-necked ibises, mainly in the former habitat, and white ibises in the latter. In mid August flocks of straw-necked ibises up to several hundred strong were moving westward across the Dividing Range via Inverell and Moree, and the subsequent build-up of numbers at the Macquarie Marshes has been described. Several hundred glossy ibises appeared in this Marsh in October 1954, and juveniles were on the wing by January 1955; there is no evidence that this species had bred there since November 1948 (Cooper 1955).

The extensive breeding of all waterbirds throughout New South Wales during 1955 and the very wet year 1956, when straw-necked ibises but not white ibises vacated some southern breeding-places, e.g. Kow Swamp (Fig. 1(*e*)), was followed by widespread drought throughout eastern Australia in 1957. During that winter and spring ibises not only moved coastwise but were forced to seek food in unusual places. In May the white ibis was reliably reported from several places in Tasmania for the first time (Green 1959*a*). Canberra city was invaded by straw-necked ibises in numbers and also by some white ibises, which fed in

gardens and on the grass verges of streets. Cairns in Queensland had a similar invasion in August 1957 (A. M. Gwynn, personal communication).

The general conclusion is that all three species of ibis in Australia are highly nomadic, especially in inland areas where floodwaters are unpredictable, but some white ibises may be more sedentary where a dependable seasonal rise in water level occurs. A further difference in the dispersal patterns of the two larger ibises is that the straw-necked ibis rarely penetrates beyond the Australian mainland, even in drought years, whereas the white ibis, in addition to its more extensive range northward, is more prone to irruptive movements; it has reached Tasmania in numbers and has even crossed the Tasman Sea. This could be related to the greater ability of the straw-necked ibis to obtain food from a wider and drier range of habitats, while the white ibis may be forced to disperse in search of the aquatic supplies on which it is so much more dependent (Carrick 1959). Finally, the recoveries of banded birds reveal no connection between age or season and distance or direction from birthplaces.

The parallel between these results on ibises and the extensive data on the grey teal, *Anas gibberifrons* Müller, discussed by Frith (1962) is very evident. The numbers, distribution, and wide nomadic movements of both ibises and grey teal are ultimately controlled by a rainfall pattern that produces unpredictable floods and resultant food supplies, and this is the key to their conservation.

IV. Conservation

The size and dispersion of populations of ibises depend upon suitable rainfall and flooding. Despite the irregularity in time and space of favourable conditions throughout most of the Australian continent, the ability of ibises to utilize them through nomadism and opportunist breeding ensures that these species are in no danger of extinction while waters continue to flow naturally. At the same time, periodic droughts will deplete their numbers regionally, and no doubt will also cause major fluctuations in the total population. It is flood prevention measures and the control of natural waters for mainly agricultural purposes that threaten the breeding of ibises and waterfowl generally, so several problems arise.

(*a*) *Aims of Ibis Conservation*

Conservation measures have to be appropriate to the purposes they envisage, which may be scientific, economic, or (for want of a better term) recreational.

The particular biological interest of ibises lies in their ecological adaptation, as essentially aquatic species, to conditions of intermittent drought and flood. Study of their breeding can throw light on how reproductive processes are geared to these special environmental conditions. Such fundamental knowledge is not without practical value, for example in the management of domesticated animals under similar conditions. Also, the preservation of a natural fauna in its entirety, and of those elements that are peculiar to a region, as the straw-necked ibis is in Australia, is necessary for evolutionary studies. And whatever the aims of conservation, the measures put into effect must be based on scientific knowledge of the ibises.

The economic value of ibises, especially the straw-necked ibis, as predators of grasshoppers and other pests has been much stressed by agriculturalists and ornithologists. There is no question that large numbers of, for example, the Australian plague locust, *Chortoicetes terminifera* (Walk.), are taken from swarms, but one particular investigation (Carrick 1959) showed that average predation pressure on large numbers of early nymphs was not sufficient to prevent swarm production. Assessment of the actual practical value of a bird species is a very complicated ecological and economic problem, but in the case of ibises it is at least simplified by the fact that, whether their benefit to agriculture is great or little, widespread or local, there are no entries on the debit side of their balance-sheet. It is conceivable that the economic significance of ibis predation on locusts could be enhanced by a heavy concentration of birds at the most opportune place and season, namely in outbreak areas in spring when, in critical years at least, sufficiently intense predation might deter swarm formation. Similar predation in autumn upon female grasshoppers about to oviposit would have a telling effect on the numbers of hoppers that hatch the following spring, but it seems doubtful whether the birds would maintain predation pressure on this relatively sparse population of female insects. It is worth exploring the possibility of manipulating ibis breeding through water control so as to create a high food demand from nestlings, followed by the dispersal of large numbers of juveniles and adults, across adjacent locust outbreak areas at the most opportune season. If it should prove possible to stimulate breeding by limited flooding, without at the same time providing the immense supply of aquatic foods that natural widespread flooding makes available, the ibises would have to concentrate on the locust nymphs. This is likely to be more successful in the case of the straw-necked ibis than the white ibis, owing to the latter's greater dependence on aquatic species. In addition to the immediate benefit, there is conceivably a long-term one stemming from the conditioning of young birds to locusts during their first experience in learning how to feed. The possibility that a marked diversity of feeding performance between individuals in the same situation may have some such behavioural explanation has been discussed (Carrick 1959). Apart from breeding conditions, the maintenance throughout the year of a low-level flow, or of intermittent freshets, might retain a more permanent ibis population exerting a steady and cumulative effect on the local invertebrate fauna.

A further aspect of the conservation of ibises is that they form part of the natural food of aborigines throughout the north of Australia.

There is a widespread appreciation of bird life as a natural amenity to be enjoyed and preserved as a desirable part of our surroundings. This aesthetic viewpoint certainly applies to ibises and similar waterfowl, and apparent threats to their survival are met with protests. The aesthetic and recreational value of wildlife is accepted in many countries, and fauna reserves are established even when economic exploitation of an area, resource (e.g. water), or species appears to be the more gainful thing to do. A marsh which is a sanctuary for waterbirds can be a place of great biological interest and beauty, and can be developed for public access on a scale that is not possible in the case of habitats with more cryptic and less

abundant fauna. Also, ibises disperse widely and become a feature of agricultural land, ponds, and estuaries far removed from their inland breeding places. Finally, although ibises are not game birds, the water refuges created to conserve them would inevitably benefit all other waterfowl, including ducks.

In the discussion that follows it is understood that the aims of conservation measures for ibises are to promote the maximum production of young annually to coincide with the spring hatching of plague locusts, and to maintain good numbers of ibises and other waterbirds in permanent reserves where their requirements can be scientifically studied and to which the public can have suitable access.

(*b*) *Biological Requirements*

The establishment of large breeding colonies of ibises at a particular time and place depends upon the availability of sufficient numbers of mature birds in a condition to respond to the appropriate water stimulus. This will be influenced by the history of breeding during the previous months, and by current breeding activity at waters within at least a hundred miles. Floodwater might be wasted if there is no nucleus of local birds to start breeding and if sufficient reserves are not present in surrounding areas to build up the colony.

Successful nesting and rearing of young ibises to the free-flying stage depends on shallow flooding that will make dormant aquatic food organisms, and drowned terrestrial ones, immediately available in quantity, and will also stimulate plant growth and consequently the breeding of insects and other ibis foods. Dry-habitat species, such as the plague locust, are outside the cause-and-effect system that normally supports breeding of ibises. Suitable nest-sites are required in or close to the floodwater; clumps of lignum surrounded by 2 or 3 ft of water are preferred and can accommodate enormous close-packed colonies of straw-necked ibises and white ibises (Plate 2, Fig. 1); beds of reeds and cumbungi are also commonly used. The deeper water gives protection from ground predators (feral pigs and cats; foxes) and the massed birds deter avian predators (swamp harrier; whistling kite). It is not precisely known whether there is an optimum rate of build-up of water depth, or a critical depth at the breeding-site, or a minimum total area that has to be flooded to stimulate breeding; these should be the subject of experiment in the establishment of a reserve. Under natural flooding conditions the area actually occupied by nests is a small part of the entire flooded area; a few acres of lignum can contain an enormous colony. In fact, from the ibis point of view, an excessive area of water more than 1 ft deep merely deprives them of some feeding-ground. An unnecessarily large wet area might minimize the foraging by adult birds into drier paddocks with locusts, and trials under various controlled water conditions are required to establish the size of flooded area that is necessary, bearing in mind alternative food supplies.

Nesting starts within a month of the onset of flooding, the incubation and fledging periods occupy almost 2 months, and colonies usually take a month or more to build up to maximum strength, therefore the flood level should be maintained during 3–4 months. It should not be allowed to recede until the last young are being fed, or losses will occur. Over the feeding area it is considered that a

few inches of water in hollows surrounded by damp soil are sufficient to stimulate the production of food required for young ibises. The inflow of water necessary to overcome losses from evaporation and seepage would also ensure fresh exchange of water in the flooded area and so prevent stagnation and consequent risk of disease such as botulism.

The amount of water, and the manner of delivery, whether as a steady flow or a series of freshets, that would be required to maintain a swamp as a sufficiently attractive feeding-place throughout the year to prevent undue dispersal of birds, would have to be determined by trial. Ibises vacate the breeding swamps when the ground is dry and the main channels are running slowly; or, in the case of lakes, when the level is down to normal and the intake, if any, is slight.

More varied water conditions than ibises alone require would be necessary to sustain the breeding of the other aquatic birds such as egrets and herons, spoonbills, cormorants, grebes (Podicipidae), pelicans, and ducks (Anatidae) that will be present and whose welfare should be considered in a waterfowl reserve. For example, deeper water is required by diving ducks and cormorants. In the case of ducks, Frith (1959) has shown how the emphasis on different plant and animal foods varies with species, and how the breeding of each species is adapted to respond to successive phases of flooding. A wider variety of nest sites, including suitable timber and tree-holes, is also required.

V. A Practical Problem: the Macquarie Marshes

The practical measures that are necessary to ensure conservation of ibises on the lines suggested include:

(i) the construction and maintenance of barriers to deliver and hold water where required to create nesting places and feeding grounds that will support breeding with the minimum expenditure of water;

(ii) control of water to meet the requirements of the birds, according to a policy that clearly defines priorities of competing claims;

(iii) protection of the colony from predation and interference;

(iv) information on the birds, the food supplies, and the nest sites to enable water to be provided in the most opportune way;

(v) assessment of results, including in the earlier years a series of field experiments to determine the best management procedures.

Each location presents its own problems, and the development of the Macquarie Marshes as a breeding reserve for ibises and other waterfowl will now be considered. This is a particularly suitable example because it is an extensive marsh system in the important Bogan–Macquarie locust outbreak area; its high capacity as a waterfowl refuge and nursery is well known, and there is information on the recent history of ibis breeding there; it is Crown land in New South Wales, much of which is leased for grazing; in 1955, it was declared a sanctuary under the Fauna Protection Act, 1948, but efforts to accord it the full protection of a dedicated fauna reserve under that Act have not succeeded; and the Burrendong Dam now in

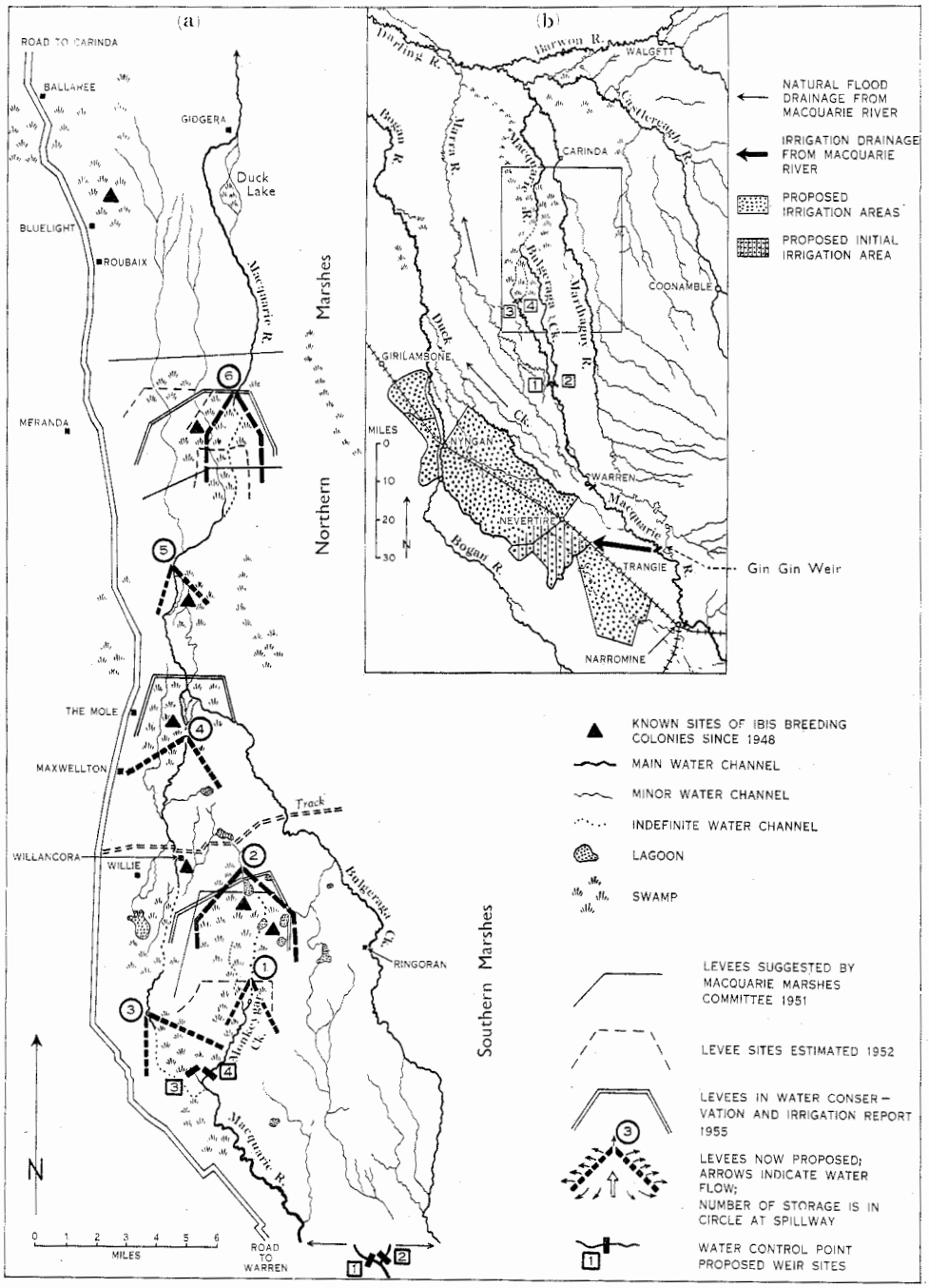

Fig. 3.—Plan of the Macquarie marshes, New South Wales, showing known recent breeding-places of ibises and suggested location of water control points and levee banks. (*a*) Central area; (*b*) Main area.

course of construction near Wellington will control the flow of the Macquarie River and provide water for new irrigation areas upstream from the Marshes, this water being drafted across to the Bogan River and thus by-passing the Marshes (Fig. 3(*b*)).

Two committees have reported on the faunal and economic values of the Macquarie Marshes, and have made recommendations on their management, while a third has considered their water requirements in relation to the Burrendong Dam and new irrigation developments. In 1943, the Advisory Committee on the Macquarie Marshes (constituted under the Department of Lands, New South Wales) listed 139 species of Australian birds that frequent the area, stressed the economic importance of many of them, considered that the granting of grazing leases, which involves risk of overstocking and impoverishment of the habitat and wildlife, should be subject to special conditions to safeguard these, and advised that the Marshes be dedicated as a National Fauna Reserve administered by a Trust with two resident rangers (see New South Wales Department of Lands 1943). In 1951, the Macquarie Marshes Investigation Committee (constituted under the Department of Conservation, New South Wales) again emphasized the agricultural and scientific importance of the fauna of the Marshes; considered the effects of the Burrendong Dam and advocated construction of levees (Fig. 3(*a*)) and provision for release of water when necessary; could find no evidence that grazing adversely affects the bird life; and recommended management of the area either by a Trust or as a dedicated Fauna Reserve by the Fauna Protection Panel (constituted under the Fauna Protection Act, 1948). Following a preliminary survey by the Water Conservation and Irrigation Commission, New South Wales, alternative sites for levees were suggested in 1952 and 1955 (Fig. 3(*a*)) (New South Wales Department of Conservation 1951). In 1957, the Macquarie River Investigations Committee (constituted under the Department of Conservation, New South Wales) submitted a comprehensive report on the development of an irrigation area in the vicinity of Nevertire (Fig. 3(*b*)) following upon the construction of Burrendong Dam, using the remaining regulated flow after, among other requirements, "having ensured that sufficient supplies are discharged into the Macquarie Marshes to maintain plant growth and wildlife". It determined the minimum annual water requirement for the preservation of the bird sanctuary as approximately 40,000 acre/ft (New South Wales Department of Conservation 1957).

The Marshes proper cover 44,000 acres and a narrow central waist connects northern and southern halves. In most years this area is flooded and useful stock feed is provided, but drainage is fairly rapid from the flat marsh area and breeding of waterfowl does not start, or may do so and fail, in the absence of follow-up floodings. The southern section upstream is more frequently floodod than the northern part. The Burrendong storage will reduce the frequency of this limited natural flooding and the annual allocation of 40,000 acre/ft is intended to compensate for this. The larger floods that cover the 800,000 acres of very level country in which the Marshes lie occur every three or four years; they will be relatively unaffected by the dam, which has provision for rapid release of water during flood periods. The question now is how to manipulate the allotted supply of water most effectively and economically, especially in the drier years.

The policy should be to establish by trial whether breeding will occur in artificial bays that would drain more slowly than the open marsh and would

TABLE 1

LOCATIONS, CHARACTERISTICS, AND WATER REQUIREMENTS DURING AUGUST–NOVEMBER OF PROPOSED BREEDING BAYS FOR WATERFOWL IN THE MACQUARIE MARSHES

These figures are approximate, pending more accurate survey of the sites

Bay Number	Location	Levee Lengths (miles)		Depth at Spillway (ft)	Water Requirement (acre/ft)		
		West	East		Capacity	Evaporation	Total
1	Monkeygar Creek, south	1·8	2	5·0	1600	1400	3000
2	Monkeygar Creek, centre	3·3	3·5	7·0	10000	6000	16000
3	Macquarie River, southern marsh, upstream	2·0	2·7	3·0	1500	2500	4000
4	Macquarie River, southern marsh, downstream	2·3	2·0	4·0	1900	2300	4200
5	Macquarie River, northern marsh, upstream	1·8	1·8	2·9	900	1300	2200
6	Macquarie River, northern marsh downstream	3·2	3·2	5·6	3700	3900	7600
Totals					19600	17400	37000
Allowance for filling creek channels and natural lagoons, losses in transit, spill over weirs, etc.							10000
Gross total							47000

require much less water than is used in general flooding. It is necessary to ascertain how this water should be supplied and distributed to meet the birds' requirements.

Water could be retained by earth levee banks meeting at an angle on a main channel, where a rock-filled spillway would control the maximum depth in the bay at this point, and the depth would reduce to nil at the open end of the bay. Rock-filled passages at ground level at about 20-chain intervals would allow seepage over surrounding ground to create feeding areas near the colony; they would also help to prevent stagnation. A series of these bays, differing in size, depth, and vegetation, sited on the main channels, and a series of regulators upstream to deliver the water to the required location (Fig. 3) would satisfy a variety of bird species and would enable selected bays to be spelled, e.g. for recovery of vegetation after nesting. Pending a more detailed survey of ground levels and the habitat, six bays with the characteristics given in Table 1 are suggested (Fig. 3(*a*)). The diversion weirs where Bulgeraga Creek and Monkeygar Creek branch from the Macquarie River would enable any pair, or combination of pairs, of bays to be watered at one time, and in times of greatest water shortage only the smallest bay (No. 1) in the southern marsh need be filled. The allowance of 40,000 acre/ft of water a year for the Macquarie Marshes would not quite fill and maintain all six bays from August to November, according to the present approximate estimate. However, storage water would seldom be used for more than two or four bays at once, so it would be possible to increase the depth and area of, say, Bay No. 2, if this were found desirable for diving species and for pelicans which like a large expanse of water. Economy and convenience would determine selection of site or sites for the first experiments, the success of which would depend on good biological information on the birds and their reactions, so that flooding could be controlled accordingly. Fences to protect the nesting colony, and the levees, from damage by stock and ground predators may be necessary.

Controlled flooding at once raises the question of policy and authority for management. Levees must be sited where vegetation and the fall of the ground favour breeding, and the same objective will determine which bays should be used each season. Flooding should start in August to ensure coincidence of ibis predation with the emergence of plague locusts, and should continue into November. Although there need be no conflict between grazing stock and breeding waterbirds, and bearing in mind that the agriculturist also stands to gain from the latter, the important consideration is that a combination of biological competence and water engineering skill are essential to achieve management procedures that will ensure the best results of waterfowl breeding with the water resources available. It would be a logical step to have these Crown Lands dedicated as a Fauna Reserve under the Fauna Protection Act 1948, to be administered by the Fauna Protection Panel in cooperation with the Water Conservation and Irrigation Commission for the primary purpose of conservation of waterfowl.

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CONSERVATION OF IBISES

Fig. 1.—Kiewa Swamp, Victoria, showing breeding habitat of straw-necked ibis and white ibis. Deeper water surrounds the reed-bed nesting-place on the right, and ibises are feeding in the shallows and wet grass beyond the water.
Fig. 2.—Juvenile white ibis soliciting food by calling and flapping the wing nearer to the parent.
Fig. 3.—Nest-site of straw-necked ibis in reeds at Kiewa Swamp, Victoria. The nestlings are panting in the heat.

CONSERVATION OF IBISES

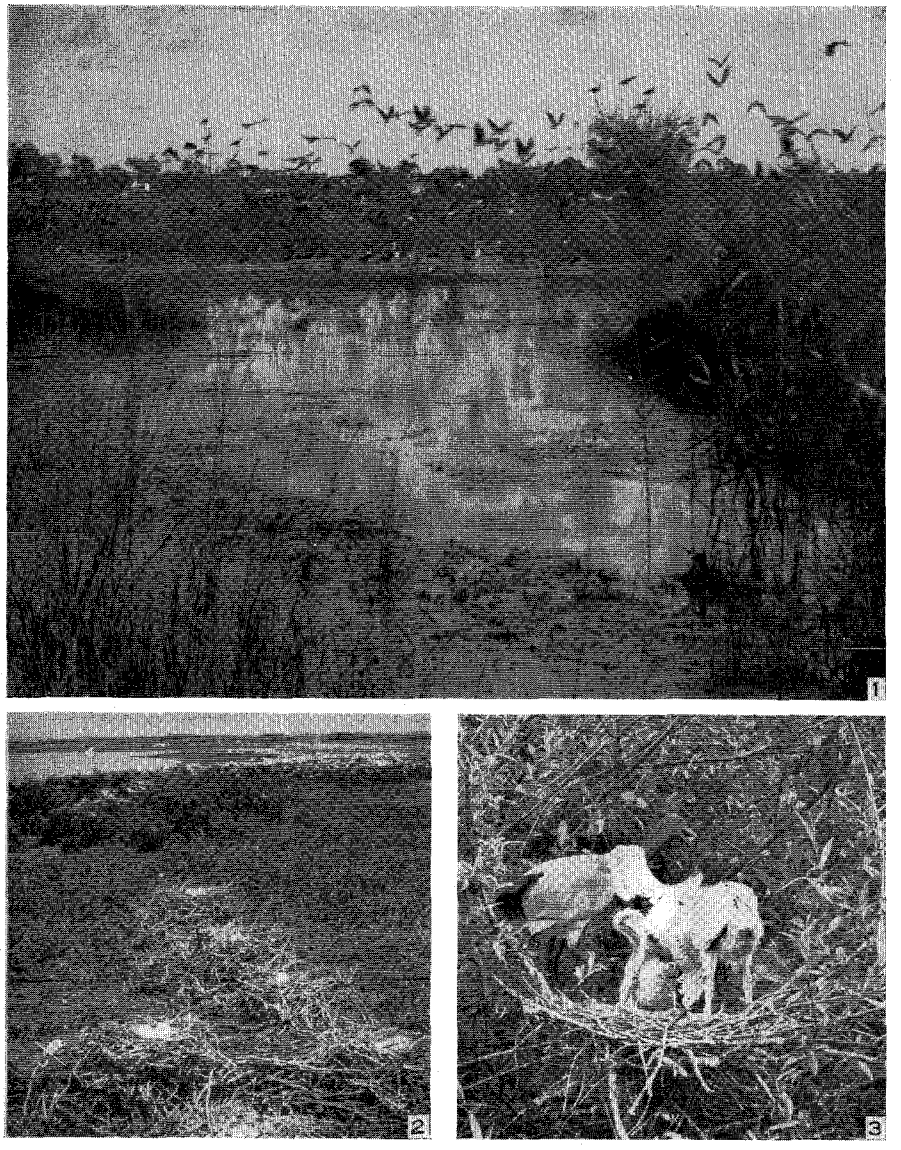

Fig. 1.—Breeding colony of straw-necked ibises and some white ibises in the Macquarie Marshes, New South Wales. Nests are on lignum surrounded by water, and juvenile birds are feeding in adjacent shallows.

Fig. 2.—Nests of straw-necked ibis on an island of dry ground at Lake Thurrumbong, Victoria.

Fig. 3.—Nest-site of white ibis in a willow tree at Ryan's Creek, Murray River, Victoria. A nestling is taking regurgitated food items from the parent's throat.